VIVEKANANDA GLOBAL UNIVERSITY, JAIPUR

OUTLINE OF PROPOSED RESEARCH INVESTIGATION FOR Ph.D. DEGREE

(Ph.D. SYNOPSIS)

1. **Name of Scholar:** Kuldeep Singh Kulhar

2. **Registration number:** VGU/2015/RES/SCH/CE/0201

3. **Title of the Research Investigation (Max. 25 words**):
   "Strength Characteristics of Sand Mixed with Randomly Distributed Jute Fibres – A New Soil Improvement Technique"

4. **Faculty/Department/Subject:** Civil Engineering

5. **Objective and Scope of the Research Investigation (Approx. 500 words):**
   (Clearly state and explain your research idea. This may take the form of a hypothesis. Provide a short over view of your proposed research- the key issue(s) that you wish to investigate. Ph.D. is an original piece of research, so you should demonstrate that your proposed topic has not been studied before or you are taking new perspective on the issue.)

Objective

Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. Soil reinforcement by randomly distributed discreet fibres is similar to the stabilization of soils by admixtures. Fiber reinforced soil has been used in many countries in the recent past and further research is in progress for many hidden aspects of it. Fiber reinforced soil is effective in all types of soils (i.e. sand, silt and clay).

For effective utilization of locally available soils in civil engineering projects, development of technically viable and economically feasible methods to improve the mechanical properties of soil to suit the requirements of engineering structures is a pre-requisite. Use of natural fibre in civil engineering for improving soil properties is advantageous because they are cheap, locally available, biodegradable and eco-friendly. The natural fiber reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of the soil. Over the last decade the use of randomly distributed natural and synthetic fiber has recorded a tremendous increase. Both natural (i.e. coir, sisal, jute, bhabhar, hemp, sabai grass etc.) and synthetic fibres (i.e. polyproplyne,

plastic, nylon etc.) being used.The Jute fibres added as inclusion are expected to provide better compact interlocking system in sand. Processing of these materials into a usable form is an employment generation activity in rural areas of these countries. If these materials are used effectively, the rural economy can get uplift and also the cost of construction can be reduced, if the material use leads to beneficial effects in engineering construction.

Natural fibers like jute, coir, sabai grass fiber etc. are mostly available in third world countries at a low cost and their supply is ensured from agriculture products. Geotextiles made from natural fibres like jute or coir are being employed as economic and eco-friendly solution (Chattopadhyay et.al, 1998, 2004, 2009). Randomly distributed fibre reinforcement can be advantageously employed as a ground improvement technique with respect to embankment, subgrade and other such problems. Of all the natural fiber Jute has highest tensile strength and withstand rotting and heat (Sen and Reddy, 2011).

The objective of this study is to identify a natural fiber to enhance the shear strength, CBR and bearing capacity of a cohesionless soil. This study includes to investigate the composite behaviour of soil through laboratory experiments for different inclusions based on fiber weight fraction, aspect ratio and soil grain size, determination of the optimum reinforcement scheme in terms of fiber's content and length and investigation of the reinforced soil through laboratory experiments on test section established and a proposed protection method to increase the durability of the selected fiber. The increase in strength is function of fiber weight fraction, aspect ratio and soil grain size. A regression analysis of test results has to be carried out to develop a mathematical model to bring out the effect of these factors on the shear strength of reinforced soil.

The study also includes to investigate the use of natural fibers in geotechnical applications and to evaluate the effects of natural fibers on shear strength of unsaturated soil by carrying out triaxial test, direct shear tests and unconfined compression tests on soil samples. The inferences are drawn towards the usability and effectiveness of fiber reinforcement as a replacement for deep foundation or raft foundation, as a cost effective approach.

Scope

The scope of the work establishes the objectives that needed to be accomplished, which are outlined below:

1. To select a natural fiber that is cheap and locally available easily.
2. To determine the fiber treatment process and apply it. We have to research methods to increase the durability of natural dried materials, with emphasis in burial conditions.
3. To obtain the compaction parameters through the Proctor Compaction test.
4. The laboratory CBR values of soil and soil reinforced with Jute fiber to be determined.
5. To investigate the effects of lengths and percentage inclusion of fiber on CBR value of soil.
6. To represent varying soil conditions for field applications, both unsoaked and soaked specimens have to be investigated.
7. The unsoaked tests have been conducted under different moisture contents (at OMC, 2% dry and 2% wet of OMC)

8. To identify the optimal stabilization parameters: the fiber content and fiber length.
9. Testing procedures: Grain Size Distribution Test (GSD), Proctor Compaction Test (PCT) and California Bearing Ratio Test (CBR), Direct Shear Test, Unconfined Compression Test (UCT), Triaxial Shear Test.
10. To carryout regression analysis of test results, to develop a mathematical model to bring out the effect of these factors on the CBR, MDD, OMC of reinforced soil. The model estimates the strength of soils reinforced with fiber content and under given stress environment. The model predictions should agree reasonably well with the experiment results and the results published in the literature.

6. Proposed Methodology (Approx. 200 words):

(Identify- how you are going to access the material and possible research methods or techniques that you will use, include some reflection on potential problems that you may face in the research process .Specify the limitation of planed methodology for investigation)

Standard Proctor compaction tests,CBR tests, direct shear tests, unconfined compression tests and triaxial shear test have to be conducted on un-reinforced as well as reinforced soil samples to investigate the strength characteristics of fiber-reinforced soil and to determine the optimum fiber % and fiber length for the reinforcement. The test results reveals that the inclusion of fibers in soil increases the CBR value, Unconfined Compressive strength and Shear strength of soil.

The optimum moisture content (OMC) and corresponding maximum dry density (MDD) for each combination is to be determined by conducting Standard Proctor tests. For each case both Unsoaked and Soaked CBR tests shall be conducted at OMC.
The results of standard Proctor tests on sand mixed with varying proportion of jute fibers of different lengths shall be investigated. The effect of adding jute fibers, of varying length and proportion by the weight of dry sand in Fine sand on different compaction characteristics are to be investigated.

MATERIAL SELECTION

A. Soil Selection

In this experimental study locally available Fine sand in villageSisiyawas is to be used which is a typical soil and is normally used in the construction of embankments and pavement subgrade in tropical countries such as India.. The Fine sand is of brown colour. The various physical properties and compaction properties (maximum dry density and optimum moisture content) of soil shall be determined in the laboratory which is tabulated in Table 1.The grain size distribution curve of soil is to be plotted.

Table 1: Physical and Compaction Properties of Soil.

S. No.	Properties		Fine sand
1	Colour		
2	Classification (IS)		
3	Specific Gravity		
4	Coefficient of uniformity, C_u		
5	Co-efficient of curvature, Cc		
6	Maximum dry density, γ_d, (gm/cc)		
7	Optimum moisture content, OMC, (%)		
8	Angle of internal friction (φ)		
9	Unsoaked California bearing ratio (%) at OMC		
10	Liquid Limit, LL (%)		
11	Plastic Limit, PL (%)		
12	Particle size distribution curve	Gravel Size (> 4.75 mm) %	
		Sand Size (0.075- 4.75 mm) %	
		Silt Size (0.002-0.075 mm) %	
		Clay Size (<0.002 mm) %	

B. Selection of fibre and experimental design parameters

Natural Jute fibers shall be collected from local market for use in this experimental study. The summary of the physical properties of fibers are given in Table 2.

The reinforcing material used in this study is Natural Jute fiber of diameter approx. 0.03 mm to 0.14 mm. The length of fiber will be taken as 5 mm, 10 mm and 20 mm. The diameter of 5 different randomly selected fibers should be considered as average diameter.

Determination of the fiber selection parameters should be the following:

- It must not be a hazard to its surroundings.
- It must be easily obtainable and inexpensive.
- Its preparation method should be simple.
- It must work with the selected soil.

Studies have also shown that coating the fibers with a protective layer could increase its durability. Fibre aspect ratio should have been mentioned (probably 400) in place of length and diameter of fibres. Even though no moisture be detected the fibers has a fairly elastic behavior. The fibers lengths available should have been mentioned.

Table 2 Summary of Physical Properties of Fibers

Tests	Jute fiber
Density (g/cc)	1.47
Diameter (mm)	0.03 – 0.14
Length (mm)	5, 10, 20

TEST PROCEDURE

To investigate the effect of inclusion of the natural jute fibers of various lengths and proportion, in Fine sand taken, a series of Standard Proctor tests and CBR tests have been conducted using Proctor mould and CBR mould as per I.S. codal provision. Different parameters considered in the experiments are given in the Table 3.

Table 3 Different parameters considered in the experiments

Type of fibres	Type of Soil	% fiber by weight of the dry sand	Fiber length (mm)
Jute fibre	Fine sand	0.5, 1.0, 1.5, 2	5, 10, 20

Jute fibers are processed by cutting into small pieces of length 5 mm, 10 mm and 20 mm for use as fiber material. The Jute fibers are randomly mixed in sand by percentage of weight of the dry sand. The mixing of fibers and sand shall be done manually with proper care for preparing homogeneous mixture at each stage of mixing. The best way to mix the fibers into the soil is to first mix the fibers into the soil before adding water. It has been found that the fibers could be mixed with sand more effectively in the moist state than in the dry state.

7. Importance of Proposed Research Investigation/ Expected outcome (Approx. 200 words):

(Establish the relevance and value of proposed research in the context of current academic thinking. Provide in brief why proposed work is important and where outcome of investigation is expected to be used.)

RESULTS AND DISCUSSIONS

(A) Effect of inclusion of Jute fibers with sand on Standard Proctor tests

As the fiber content increases, the maximum dry density (MDD) decreases, the optimum moisture content increases for Fine sand. As the fiber length increases, the maximum dry density decreases for fine sand. The decrease in density is most likely a result of the fiber having less specific weight in comparison to that of the sand grains.

(B) Effect of inclusion of Jute fibers with sand on California bearing ratio

The soaked CBR values increases with the increase in fiber inclusion (%) up to a maximum limit, after that it decreases for fine sand. The soaked CBR value is maximum for optimal % of fiber inclusion of the dry weight of sand for fine sand. The decrease of soaked CBR value above optimum content may be due to the fact that, at that fiber content, fiber quantities are higher enough to effect more fiber-fiber interaction than fiber-sand interaction.

Natural fibers like Jute are already been used for different engineering solutions in practice like improvement of sub-grade made of fine grained soils for road construction, erosion control for slopes etc. and Indian Standard Code for application of such fibers are also available (IS 14986: 2001)[15]. Jute being natural product, it degrades slowly with time. However loss of strength of jute fiber should not be of any concerns as by the time of decay of such fibers, they have already played a very important role in providing a self sustaining subgrade for most types of soils. The gain in the strength of the sub-grade, due to accelerated rate with time, can well be compensated from the loss of strength of the jute fibers within same time frame. It is opined that jute fabric is useful for developing countries of the Asia-Pacific region as a money saver as well as a construction expedient (Ramswamy and Aziz, 1989).

Jute degrades through aerobic process and jute has been found to be fairly resistant to rapid decoration when embedded permanently in wet soil below ground water table (Som and Sahu, 2003) .
In this investigation attempt has been made to visualize the use of sand in conjunction with natural fiber as alternate material to brickbats, conventionally used in construction of sub-base of road.
When jute fiber is placed within the environment surrounded by sand grains, the rate of decay of such fiber becomes slower compared to that with fine grained soils. Efficacy of using sand with jute fiber randomly mixed has to be studied experimentally in this work. It is found that soaked CBR value of sand can be judiciously improved to some extent by selecting proper percentage and length of fibers, to be mixed. Further CBR (soaked) value of such sand-jute fiber composite remains quite high even after submergence under water over a year as tested. Thus use of sand in conjunction with natural jute fibers in proper proportion, may prove extremely useful for construction of rural roads or temporary roads where routine maintenance may be utilized to check the efficacy of such use.

Advantages of soil reinforced with Jute Fiber

- Improves strength, stiffness, ductility and toughness of soil.
- Maintains strength isotropy which resists shear band formation.
- Improves the piping resistance of soil.
- Increases resistance against liquefaction under dynamic loading conditions.
- Reduces compressibility of soil.
- Reduces desiccation cracking and increase tensile strength of soil.

Thus there is significant increase in CBR value of soil reinforced with Jute fiber and this increase in CBR value will substantially reduce the thickness of pavement subgrade. Sand is also being projected as alternate material for construction of sub base of roads. Steep slopes of road embankments can be made stable using reinforced soil reducing spread width.
Fiber inclusion causes significant modification and improvement in the engineering behavior of soils.The main advantages of randomly distributed discrete fibres are the simplicity in mixing, maintenance of strength isotropy and absence of potential planes of weakness which may develop parallel to the oriented reinforcement. Use of randomly distributed fibre reinforced soils can be advantageously utilized as a ground improvement technique in the case of embankments, subgrades and in similar other problems (Pazare et al, 2002 , Jain et al, 2003, Consoli et al, 1998, Kaniraj et al, 2001)

8. Review of the work related to the field of Research- already done on the subject -Present and Past Status (Approx.200 words):

(Ground your research in existing literature. Reflect some major debates and issues and to show you're familiarly with some of the main works addressing the research issues you are proposing- demonstrating your understanding of research issues.)

Reinforcement of soils with natural and synthetic fibres is potentially an effective technique for increasing soil strength. In recent years, this technique has been suggested for a variety of geotechnical applications ranging from retaining structures and earth embankments to subgrade stabilisation beneath footings and pavements (Gray et al. 1983). Inclusion of discrete synthetic fibres in soil is one adaptation of this technique. Mixing a predetermined amount of fibre, at a particular moisture content, gives a mesh like configuration leading to a mechanical means for reinforcement of the soil matrix (Nataraj and McManis 1997).

Previous studies of sand reinforcement using fibre inclusions has been reported by Gray et al. (1983), Nataraj and McManis (1997), and Maher and Gray (1990). Similar studies for silty clay and clayey soils have been reported by Fletcher and Humphries (1991), AlWahab and Al Quirma (1995), Nataraj andMcManis (1997), andMaher and Ho (1964).

Randomly distributed fibers in soil are one of the latest techniques in which fibers of desired quality and type are added to the soil. In this technique the mixing of reinforcement in the soil is easy and no special skill is required. To develop high CBR value and to improve the compactness of sand different fiber materials like Glass fiber (Pazare et al, 2002), Nylon fiber (Jain et al, 2003), synthetic fiber (Consoli et al, 1998, Kaniraj et al, 2001) etc. are reported.

However, above inclusions are generally expensive and non-biodegradable resulting higher costs with doubtful environmental effects. This problem can be solved by using locally available natural fibers. Natural fibers like jute, coir, sabai grass fiber etc. are mostly available in third world countries at a low cost and their supply is ensured from agriculture products. Geotextiles made from natural fibres like jute or coir are being employed as economic and eco-friendly solution (Chattopadhyay et.al, 1998, 2004, 2009). In the proposed study, investigation has to be made by carrying out extensive experimentation on composite sand-jute system to examine compactive characteristics in respect of the sands used.

Fiber inclusion causes significant modification and improvement in the engineering behavior of soils. The main advantages of randomly distributed discrete fibres are the simplicity in mixing, maintenance of strength isotropy and absence of potential planes of weakness which may develop parallel to the oriented reinforcement. Use of randomly distributed fibre reinforced soils can be advantageously utilized as a ground improvement technique in the case of embankments, subgrades and in similar other problems (Pazare et al, 2002, Jain et al, 2003, Consoli et al, 1998 , Kaniraj et al, 2001)

Gray and Ohashi (1983) conducted a series of direct shear tests on dry sand reinforced with different synthetic, natural and metallic fibers to evaluate the effect of parameters, such as fiber orientation, fiber content, and fiber area ratios, and fiber stiffness on contribution to shear strength. Based on the test results, they indicated increased shear strength, increased ductility (absorbed strain energy), and reduced post peak strength loss due to the inclusion of discrete fibers. Maher and Gray (1990) conducted triaxial compression tests on sand reinforced with discrete, randomly distributed fibers and studied the influences of various fiber properties, soil properties and other test variables on soil behavior. They reported that the strength of reinforced sand increases with increase in aspect ratio, fiber content, and soil fiber surface friction.

In order to study the influence of natural fibers on the CBR value of the silty soil, Shetty and Rao (1987) performed series of laboratory CBR tests. The results of these tests show that coir fibers reinforced silty sand (SM) with the addition of coir fibers (10% by volume) resulted in increase in CBR value by 26% and 22% under soaked and unsoaked conditions respectively. Guha (1995) reveal that coir fibre differs from jute fibres in an aspect other than durability, jute fibres exhibit moderately high modulus as well as high tenacity and very low elongation at break whereas coir fibres behave exactly in the opposite manner, namely moderately low modulus, low tenacity and very high elongation at break. This difference persists irrespective of the length of coir fibre.

In the present investigation, natural jute fibers locally available in market and locally available Fine sand shall be utilized. Results of the experimental study to be made with various length and proportion of jute fibers by percentage of weight of the dry sand mixed with sand are to be reported in the paper.

9. Research Gaps identified in the proposed field of investigation - Based on review (Approx. 100 words):

(Identify existing gaps – both Theoretical and Practical that your research is intended to address.)

From review of literature it is recommended to perform the following tests to get the effect of fibre content on shear strength of soil

1. Determine the properties of the treated and non-treated fiber through tensile strength tests and measurements of the dimensions of the fibers. We will test treated and un-treated fibers to determine if the treatment has a significant effect in the strength of the fibers. If we find it has a detrimental effect, we will not apply the selected treatment process and we will only provide recommendations.

2. Evaluate the effect of fiber reinforcement on shear strength of the soil. To identify the optimal stabilization parameters: the fiber content and fiber length. Testing procedures: Unconfined Compression Test (UCT), Indirect Tensile Test (ITT) and Saturated Unconfined Compression Test (SUCT), Direct Shear Test and Triaxial Test. First we will run the UCT or the Triaxial test to obtain the effect of reinforcements with different fiber lengths and concentrations. Then we will evaluate the effect of the fiber addition to the soil tensile strength through the ITT. The results of these test will provide the optimum fiber parameters for the reinforcement.

3. To determine the benefits obtained in the soil bearing capacity.
To test the effect of the fiber reinforcement on the soil bearing capacity, we will design a testing procedure that measures the soil resistance to the insertion of a typical housing spread footing. The results of this test will determine if the reinforcement has a significantly positive impact on the soil bearing capacity. . Test the impact of an increase in shear strength on the soil bearing capacity and compare it to the bearing capacity value predicted by Terzaghi's Theory.

4. To determine the benefits from fiber reinforcement in slope stability.
The results of the tests will provide the parameters for developing models of the implementation of the reinforcement on hillsides. We will establish if the slope reinforcement is effective enough to recommend it to communities. The goal of the models is to determine the maximum slope angle a hillside can have before failure occurs at normal loading condition.

5. To analyze the results and elaborate conclusions and recommendations.
We will create a list of recommendations about how to improve the testing procedures and handling of the materials. In the conclusions section we will present what are the positive and negative effects of the fiber reinforcement and how through our model we believe would be the best way to implement the reinforcement.

6. First we will review studies of the effects of reinforcing soil with natural fibers. We will select the fibers based on the following parameters:

- It must not be a hazard to its surroundings.
- It must be easily obtainable and inexpensive.
- Its preparation method should be simple.
- It should last at least ten years.
- It must work with the selected soil.

7. Design preparation process for fibre being used should have been evolved.

8. Effect of fibre reinforcement on CBR (soaked and unsoaked) and shear strength of soil may also be evaluated at 2% dry and 2% wet of OMC.

To evaluate the real effect of the coating on the useful life of the fibers, we recommend this test to be performed in future research. A comparative study with coir fibres would have been beneficial.

To evaluate the effect of the fiber reinforcement on the shear strength of the soil, there are two options available to us: the Triaxial Test and the Unconfined Compression Strength Test (UCT). We can select the UCT (ASTM D2166) because the sample preparation time for this test is significantly shorter than the sample preparation time of the Triaxial Test. Even though the UCT provided less information than the Triaxial Test, the information is still sufficient to clearly establish the characteristics of the optimum soil fiber reinforcement scheme. Once the characteristics of the optimum reinforcement is established, we decide to test the unconfined compressive strength of completely saturated un-reinforced and optimally reinforced soil.

We recommend testing the effect of the fiber reinforcement on the shear strength of the soil through a triaxial test. This test would provide a variation of horizontal and vertical compression stresses that would allow establishing the cohesion and friction angle of each soil sample. This test would also allow performing tests on the un-drained and drained soil conditions, allowing the modelling of the behavior of soil under almost complete saturation.

It is deemed necessary to evaluate the effect of the fiber reinforcement under tensile stresses. The purpose of this evaluation would be to determine if the change in parameters of the fiber would have a significant impact on the tensile strength of the fiber. This was evaluated through Indirect Tensile Strength Test (ASTM D4123).

Table 3: Testing Procedures Test	**Study Effect**	**ASTM Standard**
Ultimate Tensile Strength	Maximum tensile strength of coated and non-coated fibers.	Similar to D638
Proctor Compaction	Optimum moisture content of non-reinforced and reinforced soil.	D698
Unconfined Compression Saturated UCT	Improvement in shear strength of soil through fiber reinforcement. Improved soil structural integrity	D2166
Indirect Tensile	Change in tensile strength of soil through fibre reinforcement	D4123
Bearing Capacity	Improvement in bearing capacity of soil through fiber reinforcement.	The procedure has to be designed
Direct Shear Test	Improvement in shear strength of soil through fiber reinforcement. Improved soil structural integrity	D3080M-11
Triaxial Shear Test	Improvement in shear strength of soil through fiber reinforcement. Improved soil structural integrity	D4767, D7181-11, D2850

10. Chapter wise details of Proposed Research Investigation Ph.D. Thesis:

(Title of each chapter along with expected contentss must be prepared in advance. It should be concise and unambiguous.)

Chapter

1. Introduction

1.1 Problem Statement
1.2 Research Objectives
1.3 Tasks of research

2. Literature Review

2.1 Mechanics of Reinforced **Soil**
2.2 Composite Behavior of Reinforced Mass

3. Experimental Work and Methodology

3.1 **Introduction**
3.2 **Material Used**
3.3 Physical Properties of soil
3.4 Jute Fiber
3.4.1 Physical Properties of Jute Fiber
3.5 Determination of Index Properties
3.6 Determination of Engineering Properties
3.7 **Experimental Methods**
3.7.1 Grain size distribution test
3.7.2 Specific gravity test
3.7.3 Water absorption test
3.7.4 LL and PL test
3.7.5 Standard proctor compaction test
3.7.6 CBR test (soaked and unsoaked, at OMC, wet and dry side of OMC)
3.7.7 Direct shear test
3.7.8 Triaxial compression test: CU test, C, Ø determination at various confining pressures
3.7.9 Unconfined Compression test etc.

4. Test Results and Discussions

4.1 Introduction
4.2 PCT test results
4.2.1 OMC
4.2.2 Maxm Dry density
4.3 CBR test results

4.3.1 Load displacement curves
4.3.2 Effect of fiber on CBR value of soil
4.4 UCT results
4.4.1 Stress versus Strain Response
4.4.2 Strength Improvement due to Fiber reinforcement
4.5 CU test results
4.5.1 Stress versus Strain Response
4.5.2 Effect of Fiber reinforcement on Soil Strength

5. Summary, Conclusions and Recommendations
5.1 Summary
5.2 Findings and Conclusions

6. Scope for Further Studies

7. References

8. Appendix

11.Expected duration of the investigation (Year wise schedule to be give):

(Provide a realistic time plan for completing your research degree. Demonstrate that your research will not take longer than planed time.)

Year	Particular	Duration in Month
2015-16	Literature Search	6 M
	Potential Lab Testing and Field Work	6 M
2016-17	Potential Lab Testing and Field Work	6 M
	Data Analysis	3 M
	Paper Publication	3 M
2017-18	Thesis Writing	3 M
	Thesis Layout	3M
	Total Time	2 Y 6 M

12. Facilities available for the investigation at scholar end and facilities required on campus:

Facilities for Testing available on campus in Geo technical Engineering lab:

S.No.	Name of test
1.	Grain size distribution test
2.	Specific gravity test
3.	Water absorption test
4.	LL and PL test
5.	Standard proctor compaction test
6.	CBR test (soaked and unsoaked, at OMC, wet and dry side of OMC)
7.	Direct shear test
8.	Triaxial compression test: CU test, C, Ø determination at various confining pressures
9.	Unconfined Compression test etc.

13. Bibliography- At least 50 relevant references (Update):

(It is unlikely that you can review all the relevant literature at this stage but you should be able to reflect issues you have proposed for investigation and work done/in progress by other workers on related issues.)

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20. Consoli, N.C., Montardo, J.P., Prietto, P.D.M., and Pasa, G.S. (2002). "Engineering behavior of sand reinforced with plastic waste*." J. Geotech Geoenviron. Eng*., ASCE, 128(6), 462-472.
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